1 559 629

# PATENT SPECIFICATION

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## (54) AN IMPROVED ELECTROSTATIC PRECIPITATOR

(71) We, NISSAN MOTOR COMPANY, Limited, a corporation organized under the laws of Japan, of No. 2, Takaramachi, Kanagawa-ku, Yokohama City, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates in general to an air cleaning device and more particularly to an electrostatic precipitator which is suitable to be mounted in a motor vehicle for cleaning the air in the passenger compartment of the vehicle.

As well known in the art, electrostatic precipitators have been widely used in numerous fields because of the ability thereof to handle a large volume of gas or air with a reasonably small pressure drop and the removal of particles in the micron range. Some of the precipitators mentioned above are equipped with so called activated carbon filters therein for absorbing harmful ozone ($O_3$) which is produced abundantly in a corona discharge area of the precipitators.

However, in the known electrostatic precipitator, high cleaning efficiency (above 90%) is only expected when the casing of the precipitator is formed to have a relatively big volume for causing the passing gas to have relatively long residence time in the casing. Thus, hitherto, the mounting of such electrostatic precipitator with high cleaning efficiency on a motor vehicle has required a large space for accommodation in an air conditioning system.

It is thus a first object of the present invention to provide an improved electrostatic precipitator which can exhibit high cleaning efficiency in spite of its compact construction.

It is a second object of the present invention to provide an improved electrostatic precipitator which is simply made by slightly modifying the conventional precipitator.

It is a third object of the present invention to provide an improved electrostatic precipitator which is appropriate for being incorporated in an air conditioning system mounted on a motor vehicle.

According to the present invention, there is provided an electrostatic precipitator for removing particles suspended in air, comprising: a casing having inlet and outlet openings through which the air is forced to pass; a high voltage electrode disposed in the casing; a collecting electrode disposed in the casing at a position adjacent the high voltage electrode; the high voltage and said collecting electrodes being connected to a power source for being supplied with direct current potential therebetween to provide both a corona discharge area where ionization of the air occurs and an electric field where charged particles drift toward the collecting electrode; additional collecting means having a polarity opposite to the high voltage electrode and disposed in the casing at a position downstream of the high voltage and collecting electrodes and an activated carbon filter disposed in said casing downstream of said additional collecting means for absorbing ozone produced at the corona discharge area.

Other objects and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings, in which:

Figure 1 is a sketch of a prior art electrostatic precipitator;

Figure 2 is an illustration for explaining the inventive steps of the present invention;

Figure 3 is a sketch of a preferred embodiment of the improved electrostatic precipitator of the present invention;

Figures 4A and 4B are sketches respectively showing the configurations of additional electrodes employable in the precipitator shown in Figure 3;

Figures 5A and 5B are sketches respectively showing box-shaped electrodes employable as the additional electrodes of Figures 4A and 4B; and

Figures 6 to 8 are sketches each showing the positional relationship between the additional electrode and an activated carbon

filter which are parts of the precipitator of the present invention.

Prior to describing the construction of the invention, an explanation of the prior art electrostatic precipitator will be given with the aid of Figure 1 in order to clarify the inventive steps of the subject invention.

In Figure 1, the prior art electrostatic precipitator is shown as being generally designated by the numeral 10. The precipitator 10 now illustrated generally comprises a casing 12 having at its left side of the drawing an inlet opening 14 and at its right side an outlet opening 16. As will be apparent hereinlater, contaminated gas or air is forced to flow in the casing 12 from the inlet opening 14 toward the outlet opening 16. Within the casing 12 and near the inlet opening 14 are disposed a plurality of spaced high voltage electrodes 18 in the form of plate which are arranged substantially parallel with each other and with the longitudinal axis of the casing 12, as viewed in this drawing. A corresponding number of corona wires 20 are connected through support member 19, which are electroconductive, to the respective high voltage electrodes 18 such that the corona wires 20 transverse the casing 12. More specifically, the corona wire 20 extends substantially perpendicularly to the surface of Figure 1, As shown, each corona wire 20 is disposed between adjacent two collecting electrodes 22 at the end of each support member 19 which is mechanically and electrically connected to each high voltage electrode 18. A plurality of spaced collecting electrodes 22 in the form of plate is also disposed in the casing 12 so as to be spaced apart from the high voltage electrodes 18 while providing an arrangement in which the electrodes 18 and 22 are alternatively positioned, as shown. A D.C. power source 24 is connected to the high voltage and collecting electrodes 18 and 22 for applying a high direct current potential between the same 18 and 22. In this drawing, the high voltage electrodes 18 and thus the corona wires 20 are shown applied with positive charge, while the collecting electrodes 22 are grounded. Near the outlet opening 16 of the casing 12 is located a fan 26 which produces an air flow passing through the casing 12 from the inlet opening 14 toward the outlet opening 16. An activated carbon filter 28 is located between the bundle of the electrodes 18 and 22 and the fan 26 for absorbing ozone ($O_3$) produced in vicinity of the corona wires 20.

With this construction of the prior art electrostatic precipitator 10, the cleaning process thereof will be carried out as follows:

The contaminated air is fed through the inlet opening 14 as indicated by an arrow and moves towards the bundle of the electrodes 18 and 22 and then reaches an electric discharge (or corona discharge) area where ionization of the air occurs. The ions thus produced collide with the particles suspended in the air and then confer thereon an electric charge, the electric charge being positive in this case. Then, the positively charged particles moves into the interior of the bundle of the electrodes 18 and 22 with air flow made by the fan 26 and drift toward the collecting electrodes 22 with the assistance of the electric field provided between the high voltage and collecting electrodes 18 and 22 and are finally deposited on the collecting electrodes 22 where their electric charge is nullified. During this operation, a considerably large amount of ozone ($O_3$) is produced in the corona discharge area, but it is absorbed by the activated carbon filter 28. Cleaned air is thus discharged from the outlet opening 16.

However, such construction of the prior art precipitator 10 involves the following drawback: There is a limit in capability of increasing the direct current potential applied between the high voltage and collecting electrodes 18 and 22. This is because there may occur an undesirable spark phenomenon between such electrodes 18 and 22 under remarkably high potential condition. This means that, under big volume of the air, high cleaning efficiency is not expected by using the above-mentioned precipitator 10. More specifically, when the rate of flow of the contaminated air is remarkably increased, by running the fan 26 faster, for blowing big volume of air, it could occur that some of the charged particles pass through the casing 12 without being trapped by the collecting electrodes 22, and in a worst case, the particles once deposited on the collecting electrodes 22 are forced to separate from the same thus reducing the cleaning efficiency of the precipitator 10. Furthermore, some of the escaped or non-trapped particles from the cluster of the electrodes 18 and 22 are unwantedly deposited on the activated carbon filter 28 thus reducing the ozone absorbing effect of the same.

Referring to Figure 2 of the drawings, there is shown a schematical illustration explaining the characteristic construction of an improved electrostatic precipitator according to the present invention. The precipitator is generally designated by the numeral 30. As seen from this drawing, the precipitator 30 comprises generally same parts as in the case of the before-mentioned conventional one 10 except for some parts. The same parts designated by numerals in Figure 1 of the conventional one are designated by the same numerals in Figure 2. According to the present invention, additional collecting electrode or means 32 is disposed between the cluster of the high voltage and collecting electrodes 18 and 22 and the activated carbon filter 28. The means 22 is connected to a D.C. power source 34 for

being applied with a high direct current potential having an opposite polarity with respect to the high voltage electrodes 18. In this drawing, the means 32 is shown applied with a negative charge. It should be noted that the negative potential for the means 32 may be applied by a negative pole of a so-called negative ion generator which is provided in the air conditioning system.

With this construction, it will be appreciated that the escaped or non-trapped particles from the collecting electrodes 22 are forced to deposit on or be trapped by the additional collecting means 32 before reaching the activated carbon filter 28. Thus, higher cleaning efficiency is achieved in this precipitator 30. Furthermore, the ozone absorbing effect of the carbon filter 28 is kept good for a long period of time.

Referring to Figure 3, there is shown an electrostatic precipitator 30*a* which embodies the invention illustrated in Figure 2. The precipitator 30*a* employs a plurality of spaced plates 32*a* as the additional collecting means 32 of Figure 2. As seen, the plates 32*a* are arranged substantially parallel with each other and with the high voltage and collecting electrodes 18 and 22 to obtain smooth air flow in the casing 12 (not shown in this drawing). The plates 32*a* may be formed with corrugations as shown in Figures 4A and 4B.

Figure 4A shows an arrangement of the plates 32*b* in which the corrugations 35 formed in adjacent two plates are arranged symmetrically with respect to an imaginary plane 33*a* located between these two plates. Figure 4B shows an arrangement in which the corrugations 35 of adjacent two plates 32*c* are arranged asymmetrically with respect to an imagnary plane 33*b* located between these two plates. Preferably, the plates 32*b* and 32*c* are arranged to allow the air to pass along and through the corrugation so that smooth air flow is provided in the casing 12. By the provision of the corrugations 35 in the plates 32*b* and 32*c*, larger collecting area is obtained on each of the plates 32*b* and 32*c*.

The additional collecting means 32 may be formed into box-shaped electrodes 32*d* and 32*e* which are shown in Figures 5A and 5B.

The box-shaped electrode 32*d* of Figure 5A comprises a rectangular enclosed framework 36 within which a plurality of vertical partition plates 38 and a plurality of horizontal partition plates 40 are disposed to intersect each other to form a plurality of square compartments 42. The setting of the box-shaped electrode 32*d* in the casing 12 is such that the longitudinal axis of each compartment 42 is substantially parallel with the axis of the casing 12 to obtain smooth air flow in the casing 12. Another box-shaped electrodes 32*e* shown in Figure 5B comprises the same element 36, 38 and 40 of Figure 5A and a plurality of inclined partition plates 44. As shown, each of the plates 44 is located on an imaginary diagonal plane defined in each square compartment to form two triangular compartments 42*a* and 42*b*. With these constructions of Figures 5A and 5B, the particle holding capacity (PHC) or the particle collecting area of the additional collecting means 32 is remarkably increased. In addition to these configurations of the compartments 42, 42*a* and 42*b*, a honeycomb configuration may be also possible.

Figures 6 to 8 show respectively other examples of the additional collecting means 32.

In the case of Figure 6, a wire-netting 32*f* is used as the additional collecting means 32. The member 32*f* is disposed between the bundle of the electrodes 18 and 22 and the activated carbon filter 28 in such an arrangement that an imaginary plane containing a front surface of the member 32*f* is perpendicular to the axis of the casing 12.

In Figure 7, a wire-netting 32*g* is used to construct a front frame member of the activated carbon filter 28.

In the case of Fig 8, a wire-netting 32*h* is used for constructing a casing of the activated carbon filter 28.

With these constructions of Figures 6 to 8, the precipitator of the invention can be made compact due to the use of the thin wire-netting member arranged substantially perpendicular to the axis of the casing 12. The precipitator employing the construction of Figure 8 will exhibit higher cleaning efficiency than those employing the constructions of Figures 6 and 7 since the air is forced to pass twice through wire-netting sections in the case of Figure 8. It should be noted that the wire-cutting 32*f*, 32*g* or 32*h* may be substituted by a perforated metal plate.

It should be also noted that, if the additional collecting means 32 is detachably set in the casing 12, the cleaning of the means 32 is very much facilitated since it can be done under a condition where the means 32 is removed from the casing 12.

It will be now appreciated from the preceding description that the electrostatic precipitator according to the present invention has a high cleaning efficiency in spite of its compact construction and thus the subject precipitator is appropriate for mounting on a motor vehicle.

WHAT WE CLAIM IS:—

1. An electrostatic precipitator for removing particles suspended in air, comprising:

a casing having inlet and outlet openings through which the air is forced to pass;

a high voltage electrode disposed in said casing;

a collecting electrode disposed in said casing at a position adjacent said high voltage electrode;

said high voltage and said collecting electrodes being connected to a power source for being supplied with direct current potential therebetween to provide both a corona discharge area where ionization of the air occurs and an electric field where charged particles drift toward said collecting electrode;

additional collecting means having a polarity opposite to said high voltage electrode and disposed in said casing at a position downstream of said high voltage and collecting electrodes and an activated carbon filter disposed in said casing downstream of said additional collecting means for absorbing ozone produced at the corona discharge area.

2. An electrostatic precipitator as claimed in Claim 1, in which said high voltage electrode includes a wire member for providing said corona discharge area.

3. An electrostatic precipitator for removing particles from air in which the particles are suspended, said precipitator comprising:

a casing having inlet and outlet openings through which the air is forced to pass;

a plurality of spaced high voltage electrodes disposed in said casing in the vicinity of said inlet opening, each of said high voltage electrodes being equipped with a corona wire;

a plurality of spaced collecting electrodes disposed in said casing in the vicinity of said inlet opening, said high voltage electrodes being interposed alternately between said collecting electrodes;

a power source for applying a direct current potential between said high voltage and collecting electrodes to produce both corona discharge areas between said corona wires and said collecting electrodes, and electric fields between said high voltage and collecting electrodes;

additional collecting means having a polarity opposite to said high voltage electrodes and disposed in said casing at a position downstream of said high voltage and collecting electrodes for collecting the particles passed by said collecting electrodes and an activated carbon filter disposed in said casing downstream of said additional collecting means for absorbing ozone produced at the corona area.

4. An electrostatic precipitator as claimed in Claim 3, in which said additional collecting means comprises a plurality of spaced plates which are arranged substantially parallel with the longitudinal axis of said casing.

5. An electrostatic precipitator as claimed in Claim 4, in which each of said plates has corrugations.

6. An electrostatic precipitator as claimed in Claim 4, in which the corrugations of adjacent two of said plates are arranged symmetrically with respect to an imaginary plane located between these two plates.

7. An electrostatic precipitator as claimed in Claim 5, in which the corrugations of adjacent two of said plates are arranged asymmetrically with respect to an imaginary plane located between these two plates.

8. An electrostatic precipitator as claimed in Claim 3, in which said additional collecting means comprises an enclosed frame member disposed at said position in the interior of the casing to face said inlet and outlet openings of said casing, and a plurality of mutually intersected partition wall members disposed in said enclosed frame member to form a plurality of compartments each having inlet and outlet openings respectively facing said inlet and outlet openings of said casing.

9. An electrostatic precipitator as claimed in Claim 3, in which said additional collecting means is a perforated member selected from the group consisting of a wire-netting and a perforated metal plate.

10. An electrostatic precipitator as claimed in Claim 9, in which said perforated member is disposed at said position such that an imaginary plane containing one side surface of said perforated member is substantially perpendicular to the axis of said casing.

11. An electrostatic precipitator as claimed in Claim 10, in which said perforated member is arranged to construct part of a casing of said activated carbon filter.

12. An electrostatic precipitator as claimed in Claim 9, in which said perforated member is arranged to construct a casing of said activated carbon filter.

13. An electrostatic precipitator as claimed in Claim 3, in which said high voltage and collecting electrodes are plate members and said collecting electrodes are gounded.

14. An electrostatic precipitator constructed and arranged substantially as described herein with reference to Figures 2 to 8 of the accompanying drawings.

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Sheet 1

FIG. 1
PRIOR ART

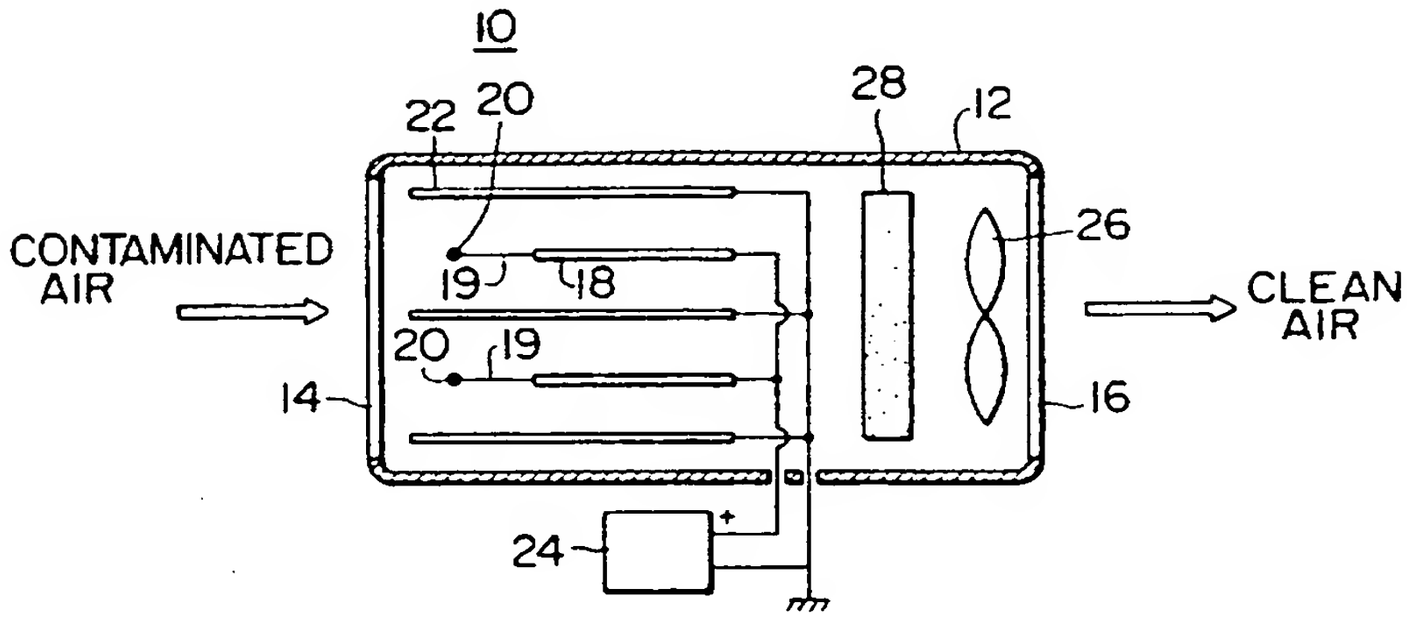
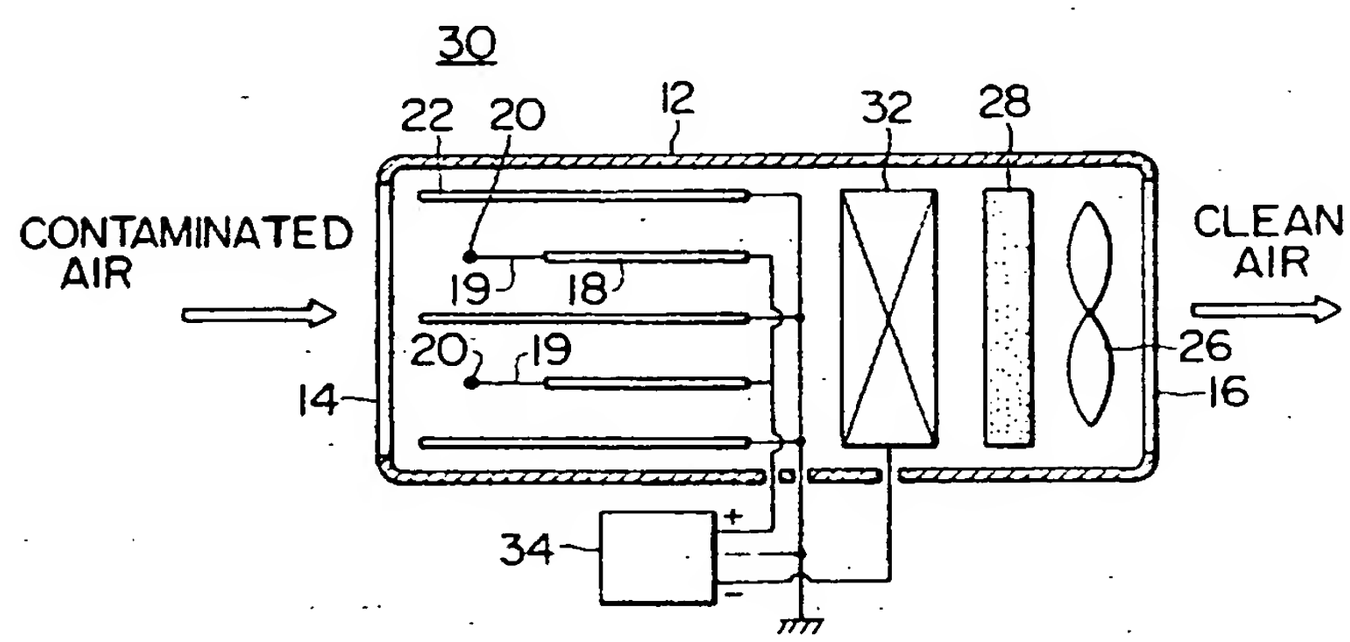



FIG. 2



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Sheet 2

FIG. 3

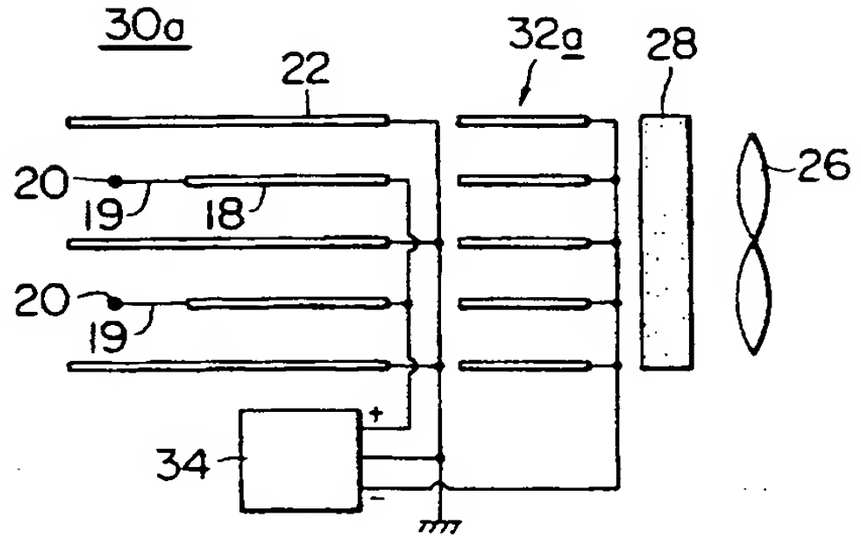



FIG. 4A

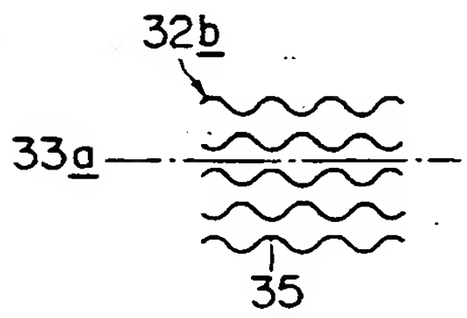



FIG. 4B

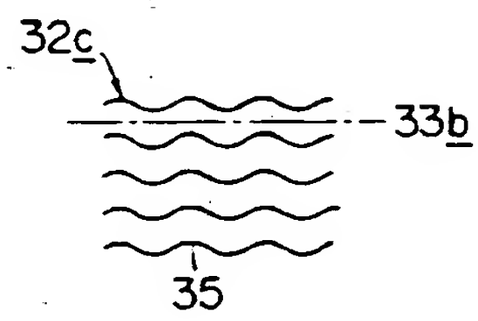



FIG. 5A

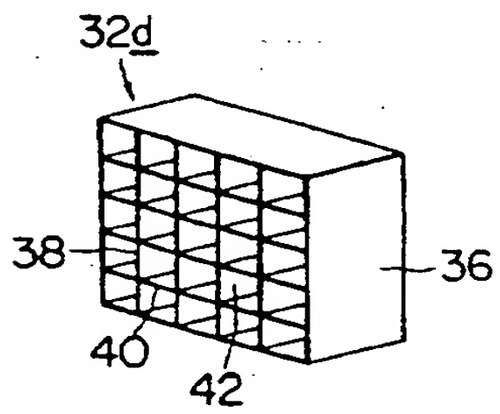
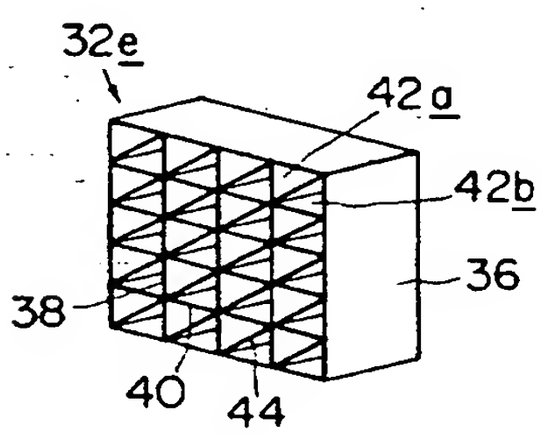



FIG. 5B



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Sheet 3

FIG. 6

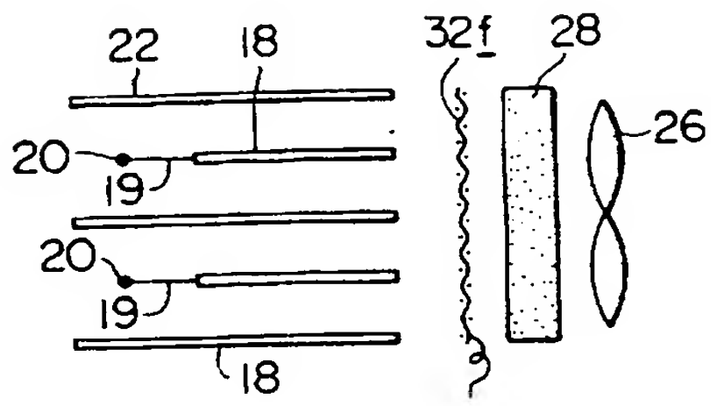


FIG. 7

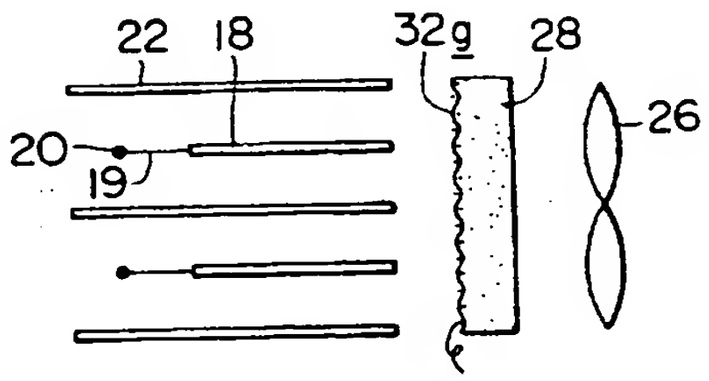


FIG. 8